

# REFRACTORIES FOR THE GLASS INDUSTRY

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## RATIONAL USE OF REFRACTORIES AND OPTIMUM DESIGNS OF REGENERATOR CHECKERWORK IN GLASS-MELTING FURNACES

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Data on the main service properties of melted-cast and fired refractories are given, whose application in regenerators of glass-melting furnaces ensures the long-time service life of checkerwork without hot repairs involving its replacement. An evaluation of the thermal efficiency of different shapes of checkerwork is given.

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The main thermal and technological facility in glass production is a regenerative continuous glass-melting tank furnace. Two types of furnaces are most common: direct-flow furnaces with lateral direction of the flame (mostly for sheet glass) and flow-through furnaces with a horseshoe-shaped flame (for container glass). The obvious advantages of the second type of furnaces with respect to the cost of construction and their thermal efficiency in operation promoted their extensive application in producing container glass. These furnaces call for the development of efficient and resistant checkerwork, which can guarantee the continuous service life of regenerators during the whole campaign of the furnace (8 – 10 years). Sometimes, in practice, checkerwork in furnaces with the lateral direction of the flame can be replaced during the campaign, although this requires substantial material and labor input, but to do so in a furnace with a horseshoe-shaped flame is virtually impossible. Accordingly, the wear of regenerator checkerwork becomes the limiting factor in the campaign of the glass-melting furnace.

Checkers experience drastic conditions during the entire service life: a constant (after each 20 – 30 min) change of the direction of air and waste flue gases; the temperature of the gas medium in the upper part of the checkerwork varies from 1550 – 1600°C to 1100 – 1300°C and in the lower part from 400 – 500 to 650 – 750°C. The waste gases also have a high concentration of dust-like glass batch components and aggressive gaseous media generated in fuel combustion and in glass-melting.

With respect to the corrosive effect, the checkerwork of a regenerator can be divided along its height into three zones. The refractories of the upper zone (3 – 5 rows of the brick-

work) experience mostly the effect of solid dust-like batch components (dolomite, lime, fine fractions of quartz sand) as well as nickel and vanadium compounds contained in the fuel combustion products. The refractories of the middle zone of the checkerwork (50 – 60% of the total height) at 1100 – 1450°C mostly experience the effect of aggressive gaseous products. The service conditions of the lower zone of the checkerwork (30 – 40% of the total height) are very severe due to aggressive sulfates of alkali and, to a lesser extent, alkali-earth metals, which condense at 800 – 1100°C. Finally, the lowest (2 – 3 rows) part of the checkers and the arches under the checkerwork at temperatures below 750°C mainly experience thermal cycling and to a small extent the effect of aggressive sulfate compounds that condense on them.

A rational selection of refractories for various zones of checkerwork depending on the specifics of the corrosion process in each zone is currently based on two groups: melted-and-cast and fired materials.

The SEPR company (France) produces melted-cast checkerwork. They have developed and made checkers from three types of refractories: ER 1682 RX, ER 1621 RX, and ER 5312 RX (Table 1).

Considering the specifics of the service of refractories in various zones of checkers, SEPR recommends the following variants for using the proposed materials:

- ER 5312 RX for the upper zone of the checkerwork (10 – 20% of the total height) of regenerators in furnaces with horseshoe-shaped flame direction and for the melting-zone regenerators in furnaces with lateral flame;
- ER 1682 RX for the middle and lower zones of regenerator checkers in the same furnaces and also for the total

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TABLE 1

Parameter	Refractory		
	ER 1682 RX	ER 1621 RX	ER 5312 RX
Chemical composition, %:			
Al <sub>2</sub> O <sub>3</sub>	50.6	55.8	87.5
ZrO <sub>2</sub>	32.5	15.0	—
SiO <sub>2</sub>	15.6	23.5	0.5
Na <sub>2</sub> O + impurities	1.3	5.0	1.3
MgO	—	—	7.5
Apparent density, kg/m <sup>3</sup>	3300	3120	2900
Compressive strength, MPa	210	160	60
Temperature of deformation under load of 0.2 MPa, °C	1700	1600	1750
Thermal conductivity, W/(m · K), at temperature, °C:			
500	4.0	3.6	2.1
1000	4.0	3.9	3.3
1500	5.5	5.7	6.1

height of regenerators in the maximum-temperature zones in furnaces with lateral flame;

– ER 1621 RX for regenerator checkers of the clarification zone in furnaces with lateral flame and the second (cold) chamber in a two-pass regenerator, in both cases for the total height of the checker.

The practice of using the above listed refractories (in the last 25 years) at glass factories of many countries indicated the feasibility of the checkerwork serving without replacement during a long furnace campaign (up to 10 – 12 years).

Another, just as effective, variant is making regenerator checkers from highly resistant fired refractories of various compositions developed specially for service in specific severe conditions. The Veitscher company (Austria), which is part of the consortium VRD in Europe, produces refractory

TABLE 2

Parameter	Refractory				
	Anker DG 1	Anker DG 11	Anker DG 3	Rubinal VZ	Rubinal EZ
Chemical composition, %:					
MgO	97.0	97.0	95.0	78.0	75.0
ZrO <sub>2</sub>	—	—	—	12.5	12.5
Al <sub>2</sub> O <sub>3</sub>	0.1	0.1	0.1	0.3	0.2
SiO <sub>2</sub>	0.6	0.5	3.0	8.0	10.0
Fe <sub>2</sub> O <sub>3</sub>	0.1	0.1	0.5	0.4	0.4
Apparent density, kg/m <sup>3</sup>	3000	3090	2960	3190	3100
Open porosity, %	15.5	13.0	15.0	11.0	14.0
Compressive strength, MPa	80	90	60	130	100
Temperature of deformation under load of 0.2 MPa, °C	1700	1700	1700	1670	1570
Thermal conductivity, W/(m · K), at temperature, °C:					
400	7.9	7.9	7.9	2.8	2.8
700	6.0	6.0	8.4	2.7	2.7
1000	4.6	4.6	4.6	2.7	2.7

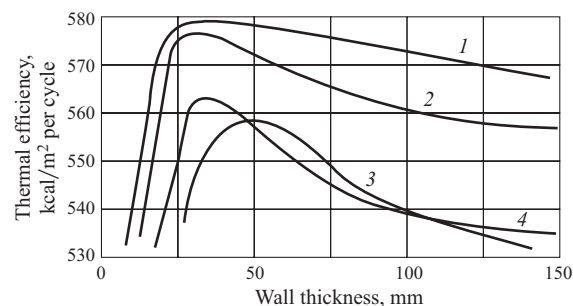


Fig. 1. Thermal efficiency of various types of refractories serving as regenerator checkerwork in glass-melting furnaces: 1) ER 1682 RX; 2) periclase; 3) chamotte; 4) dynas.

materials for this purpose, whose chemical compositions and properties are shown in Table 2.

The following refractory materials have shown the best effect in service in various zones of the checkers:

– Rubinal VZ for the upper rows of the checker; a protective layer of forsterite is formed on the surface of the periclase grains under the high-temperature effect of the dust-like fractions of quartz sand, which prevents further corrosion of the refractory;

– Anker DG 1 and Anker DG 11 for the middle zone of the checkerwork; the materials in this zone are virtually not destroyed, since they are high-purity periclase refractories with good high-temperature properties;

– Rubinal EZ for the lower zones of the checker; a protective layer of forsterite and baddeleyite crystals is formed on the surface of the periclase grains in the structure of this periclase-zircon refractory at high temperatures. This layer has high corrosion resistance to the aggressive effect of the melt of condensing sulfates of alkaline and alkaline-earth metals, which prevents further corrosion of the materials;

– Anker DG 3 for regenerator checkerwork in the clarification zone in furnaces with lateral flame direction and in the second chamber of the two-pass regenerator in furnaces with the horse-shoe-shaped flame.

The specified fired refractories rationally used in regenerators also ensure their continuous service without hot repairs during the total campaign of the glass-melting furnace.

The contemporary requirements imposed on regenerators are not confined to an extremely long service life. It is essential to maintain a high efficiency of regenerators in a long campaign of the glass-melting furnace (see Fig. 1). An example can be seen in the brand Cruciform made from the melt-cast refractories developed by SEPR (Table 1). The most typical products are drawn in Fig. 2. Just as effective is the “cup-shaped” product Topfstein developed by Veitscher from sintered refractories (Table 2). Figure 3 shows two variants of these products. The most important

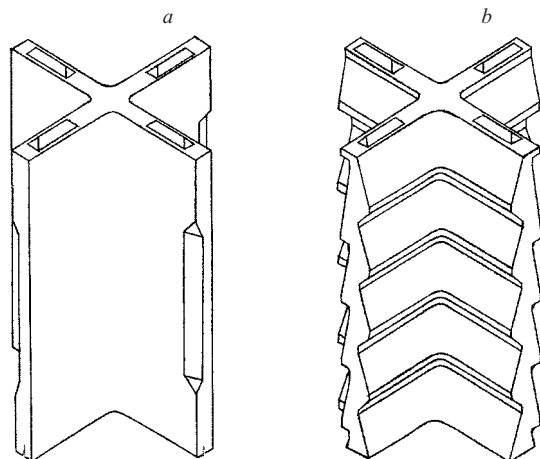


Fig. 2. Cruciform checkers: types 3 (a) and 4 (b).

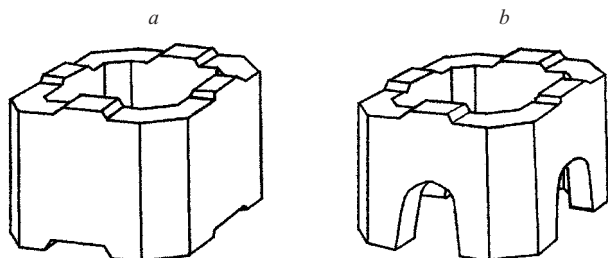


Fig. 3. Topfstein checkers: types TG (a) and TL (b).

parameters of the checkers with the cell size  $150 \times 150$  mm are indicated in Table 3.

The Institute of Glass (Moscow) more than 20 years ago developed a melted-cast chromium-corundum refractory material XK-20 for regenerator checkerwork of the glass-melting furnace and several types of checkers (these designs are protected by inventor's certificates). A trial lot has been produced. The industrial testing of these products in a high-temperature regenerator of an industrial glass-melting furnace demonstrated the high resistance of the checker elements, which made it possible to predict a continuous life of the checker up to 10 years. It should be noted that the source of material for these products was industrial waste, namely, waste catalyst generated by the caoutchouc production IM 2201 with small additives of technical materials, which significantly decreases the production cost. However, the production of melted-cast chromium-corundum products needed by the domestic glass industry was never implemented on the commercial scale.

As for the production of fired checkers of magnesium composition, the only Russian producer of a wide range of high-quality products of this class is the Magnezit Works (Satka, Chelyabinsk Region). Until early 1990s the production of magnesium products at that company was totally intended for metallurgy and the glass factories had to make re-

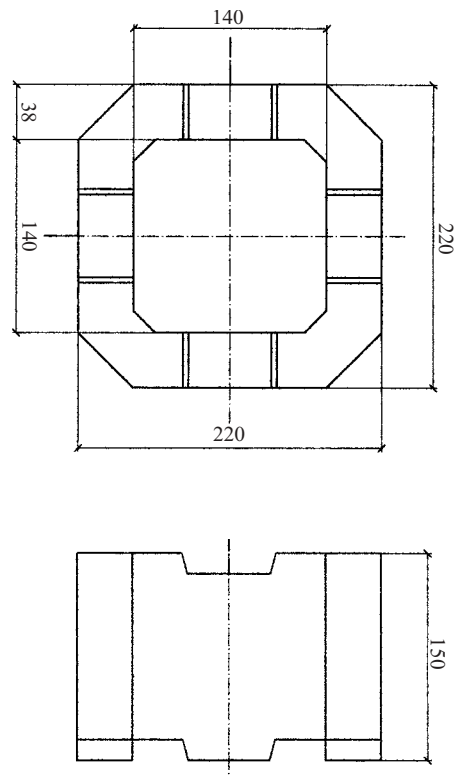


Fig. 4. Design of a regenerator checker for glass-melting furnace produced by the Magnezit Works.

generator checkerwork from chamotte (service life up to 1 year) or, less frequently, from mullite-silica and forsterite (up to 2.5 years) refractory bricks.

Later some glass works (for instance, Salavatsteklo JSC) used periclase brick P91 and P-90 (GOST 4689-94) produced by the Magnezit Works for checkerwork, which extended the service life of checkers without replacement up to 3.5–4 years and in some cases up to 5 years. However, it has not yet been possible to avoid hot repairs involving replacement of checkers during a long campaign of the furnace, since the composition and properties of the specified

TABLE 3

Checker parameters*	Cruciform		Topfstein	
	type 3	type 4	TG	TL
Article height, mm	420	420	150	150
Specific surface area of heating, $\text{m}^2/\text{m}^3$	15.6	18.6	17.4	18.9
Specific density of checkers, $\text{kg}/\text{m}^3$ , made from refractory:				
ER 5312 RX	710	820	—	—
ER 1682 RX	725	830	—	—
Rubinal VZ	—	—	945	830
Anker DG 1	—	—	890	780
Rubinal EZ	—	—	920	805

\* Wall thickness in all cases is 30 mm.

periclase refractories do not meet the drastic service requirements, especially in high-temperature furnaces with a glass melt output over 1.8 – 2.0 tons/m<sup>2</sup> per day.

It should be noted that the Magnezit Works has vast experience in producing high-quality periclase refractories that satisfy the contemporary requirements (for instance, products made of melted-cast periclase PPLU-95 with a MgO content not less than 95%, periclase products PDF and PF with the same MgO content, periclase products PLK with a content of MgO of at least 94.5%, etc.). Furthermore, the Magnezit Works has vast experience in producing various complex products from periclase refractories, which, undoubtedly, makes it possible to organize the production of checkers of optimum design. This will not only ensure a long

service life for regenerator checkerwork without replacement during the furnace campaign but also provide for high thermal efficiency.

The first step in this direction is the production of an industrial lot of checkers represented in Fig. 4 for the Borskii Glass Factory. The majority of these products contain not less than 96% MgO with open porosity up to 15%, compressive strength in the range of 80 – 90 MPa, and softening temperature under loading not lower than 1640°C. This points to the possibility of fundamental extension of the service life of checkerwork and an increase in its thermal efficiency compared with checkerwork made of periclase refractory bricks P-91 and P-90.